BRAKE SYSTEMS IMPROVEMENTS

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Introduction

Automotive brake systems are essentially an energy conversion device which converts kinetic energy into heat energy. Various noncritical failure modes, mostly related to noise and vibration problems can occur during brake operation and are often related to thermal phenomena. These problems are of significant cost to the industry and are a quality concern to automotive OEMs and vendors. The User and Fellowship Programs at the High Temperature Materials Laboratory, Oak Ridge National Laboratory, are complementing the industrial program at Ford Motor Company by providing access to unique facilities and measurement expertise.

Objectives and Approach

Ford Motor Company has utilized ORNL facilities and expertise to expand upon and complement the research efforts at Ford Motor Company's Scientific Research Laboratory. Work to date at ORNL by Ford has taken advantage of the following capabilities:

- Through-thickness residual stress mapping
- Frictional stability measurements of brake pads
- Thermophysical properties of various grey cast iron specimens
- Direct observation of thermoelastic instabilities in brake systems

The HTML Neutron Residual Stress Facility located at ORNL's High Flux Isotope Reactor was used to map residual strains and to calculate the residual stresses within a brake disc. It is believed that residual stresses may change the rate of deformation of the discs during severe braking conditions when the disc temperature is increased significantly. Neutrons are able to map elastic strains and the strain gradients at locations within the thickness of specimens due to the low attenuation of neutrons in most engineering materials. Neutron diffraction was used to map the residual strains in a production brake disc before and after a stress-relieving heat treatment. Internal hoop, radial and axial strains were measured along the radius at mid thickness of the inner and outer discs. Using diffraction elastic constants the elastic strains are converted to residual stresses.

Frictional stability under wet and dry conditions of commercial automotive brake pad materials was characterized using ORNL's controlled-atmosphere pin-on-disk test facility. Two cases were studied: tests with the interface flooded with water and tests in ambient air at 62% RH.

The role of graphite flake morphology on thermal diffusivity at room and elevated temperatures was determined by SEM and Laser Flash Thermal Diffusivity (LFTD) methods. The LFTD measurements were obtained at room temperature and elevated temperatures. Specific heat and the linear coefficient of thermal expansion were also determined.

A high sensitivity, high speed, 256 x 256 pixel IR camera was used to directly image brake discs during dynamometer testing. The IR camera was able to accurately determine the temperature and its temporal changes across both the inner and outer surfaces of the brake disk. The calibration showed the camera's measurement to be accurate to ±1°C.

Results and Discussion

The neutron residual strain measurements show that the strains along the inboard disc centerline are compressive, that there is considerable variation of strains from disc to disc and at different azimuthal locations within a disc, and that the strains are considerably reduced by heat treatment. However, the magnitudes of the stresses in the cast production brake rotor are small, and therefore the reduction in stress resulting from heat treatment has to be compared to the cost of the annealing process.

The frictional stability studied showed during coast-down tests that friction spikes were observed for wet sliding only. Interfacial moisture suppressed the formation of thin transfer layers on the cast iron sliding surface and resulted in the tendency to "grab" just before stopping.

Thermal diffusivity is influenced by subtle changes in chemical composition of grey cast iron. A roughly linear relationship exists between room temperature thermal diffusivity and carbon equivalent (CE). For a given CE, microstructures that are not 100% Type A graphite flake exhibit reduced thermal diffusivity. When chemical composition is constant, there is a strong correlation between average flake length for Type A graphite flakes and thermal diffusivity

Localized hot spots on brake rotors spinning at 600 rpm were observed and quantitatively measured in both temperature, time, and location by use of a high speed, high sensitivity IR camera. A snapshot of the brake disk surfaces can be taken each revolution of the disc. Hot spots have been observed moving around the rotor circumferentially as well as radially. Individual hot spots may also split into multiple hot spots. The quantitative measurements will be compared with thermo-elastic predictions from modeling efforts. Hot spots cause localized thickness variations in the rotor which result in torque variations. Such torque variations can result in vibrations in the steering wheel as well as the body of the car.

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